TOPIC 02 – ATOMIC STRUCTURE
2.1: THE ATOM

IB Chemistry

T02D01

2.1 The atom - 1 hour

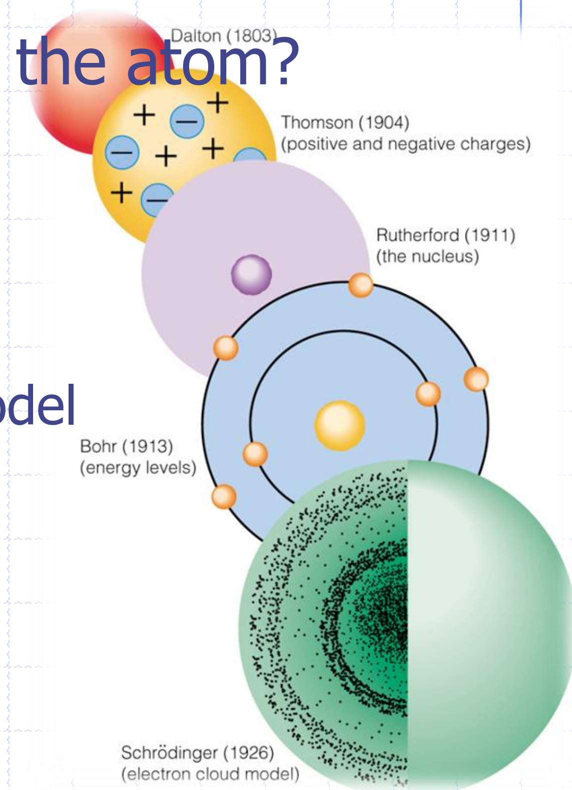
- 2.1.1 State the position of protons, neutrons and electrons in the atom. (1)
- 2.1.2 State the relative masses and relative charges of protons, neutrons and electrons. (1)
- 2.1.3 Define the terms mass number (A), atomic number (Z) and isotopes of an element. (1)
- 2.1.4 Deduce the symbol for an isotope given its mass number and atomic number. (3)
- 2.1.5 Calculate the number of protons, neutrons and electrons in atoms and ions from the mass number, atomic number and charge. (2)
- 2.1.6 Compare the properties of the isotopes of an element. (3)
- 2.1.7 Discuss the uses of radioisotopes. (3)

2.1 – The Atom

- 2.1.1 – State the position of protons, neutrons and electrons in the atom
- Atoms have two main parts, the nucleus and the electron shells.
- The atom is composed of three sub-atomic particles
  - Protons (nucleus)
  - Electrons (electron shells)
  - Neutrons (nucleus)
- The model of the atom we generally draw is known as the Bohr model

2.1 – Atomic Theory

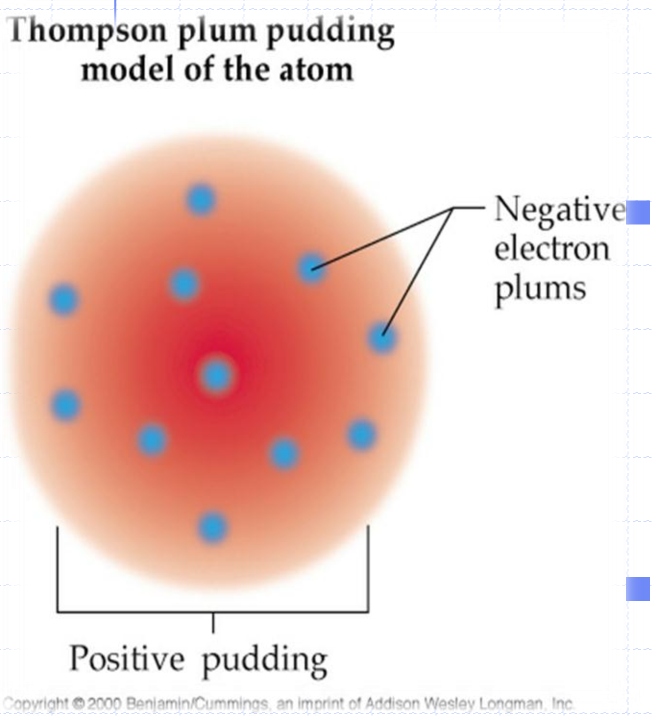
- Why do we believe what we believe about the atom?
  - John Dalton (1766-1844)
    - Proportions – Billiard Model
  - J.J. Thomson (1856-1940)
    - Cathode Ray Tubes (CRT) Plum Pudding Model
  - Ernest Rutherford (1871-1937)
    - Gold Foil Experiment – Empty Space Model
  - Niels Bohr (1885-1962)
    - Spectra of atoms – Planetary Model
  - Erwin Schrodinger (1887-1961) & Werner Heisenberg (1901-1976)
    - Waves & Uncertainty – Quantum Model



2.1 – Dalton: Billiard Model

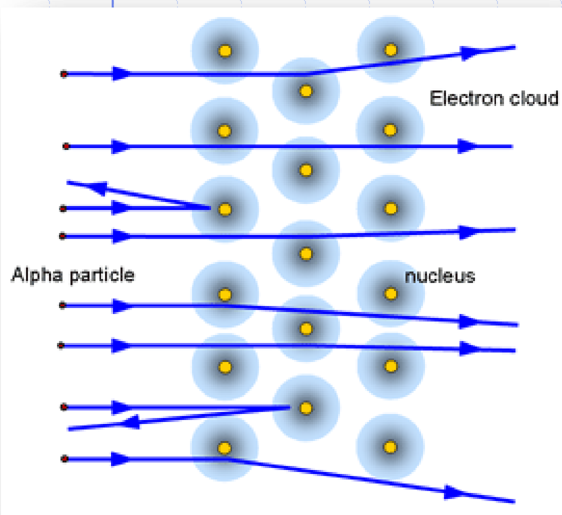
- Matter is composed of tiny particles called atoms
- All atoms of a particular element are identical in size, shape, and properties
- Atoms are indivisible, indestructible
- During chemical changes, atoms of different elements unite to form compounds
- When atoms combine they do so in definite whole number ratios by weight (Law of Definite Proportions)

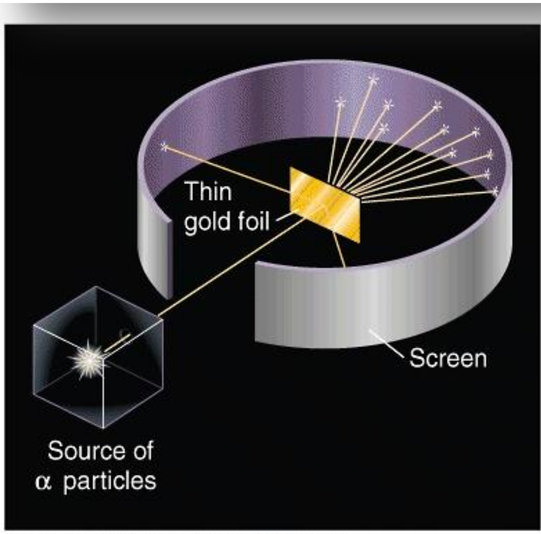
2.1 – Thomson – Plum Pudding Model



- High voltages were sent across electrodes in a vacuum, producing an electrical discharge which traveled in a straight line
- When a magnetic field was applied the rays were deflected, therefore there must be electrical charges in the field.
- The direction of the deflection relative to the magnet indicated the charge was negative
- Was able to measure the electrons charge to mass ratio (e/m)

2.1 – Rutherford – Empty Space

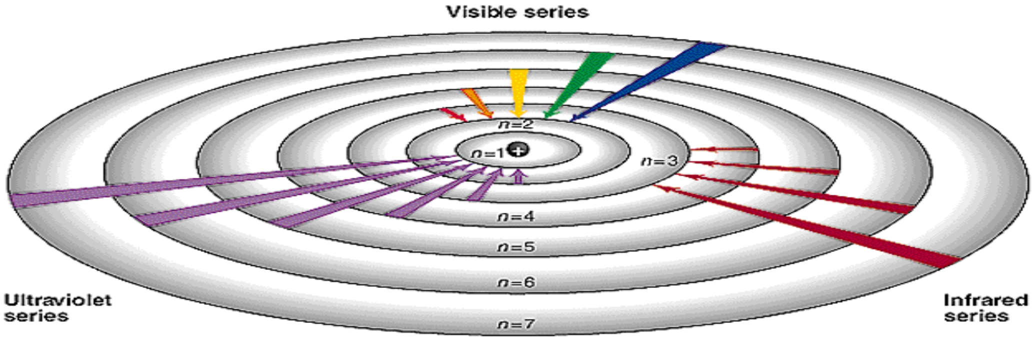




- Used isotopic radium, (isolated by the Curie's) which was an alpha-emitting radioisotope, and fired the particles at thin gold foil.
- If Thomson's model was correct the particles would have been absorbed or only slightly deflected
- BUT, 99% passed through, and some bounced back!
- Proposed a dense, positively charge nucleus and a large amount of empty space surrounding

2.1 – Bohr – Planetary Model

- To simplify Bohr's work, a flame test can be considered.
- When various materials are placed in a flame, a varying color is produced based on the electron structure of the material.
- Bohr proposed that there must be quanta, or energy levels, in which electrons travel around the nucleus



2.1 – Crazy Dudes – Quantum Model

- Finally, Erwin Schrodinger, Werner Heisenburg, and many others contributed to the current accepted model of the atom, Quantum Theory
- The electron occupies three dimensional space defined by four quantum numbers
  - **Principle Quantum Number**, shell (n)
  - **Angular Quantum Number**, shape (l)
  - **Magnetic Quantum Number**, subshell (m_l)
  - **Spin Quantum Number**, spin (m_s)
    - Luckily these are not needed for IB, but worth noting!

2.1.2 – Relative Mass and Size

- 2.1.2 – State the relative masses and relative charges of protons, neutrons and electrons

Sub-atomic Particle	Symbol	Relative Mass	Relative Charge	Nuclide notation
Proton	p	1	+1	$^{1}_{1}p$
Neutron	n	1	0	$^{1}_{0}n$
Electron	e	$5x10^{-4}$	-1	$^{0}_{-1}e$

- Neutrons help stabilize the nucleus, separating protons. (if too many/few n, radioactive)
- Electrons control the chemical properties of the elements
- Protons identify an atom as a specific element

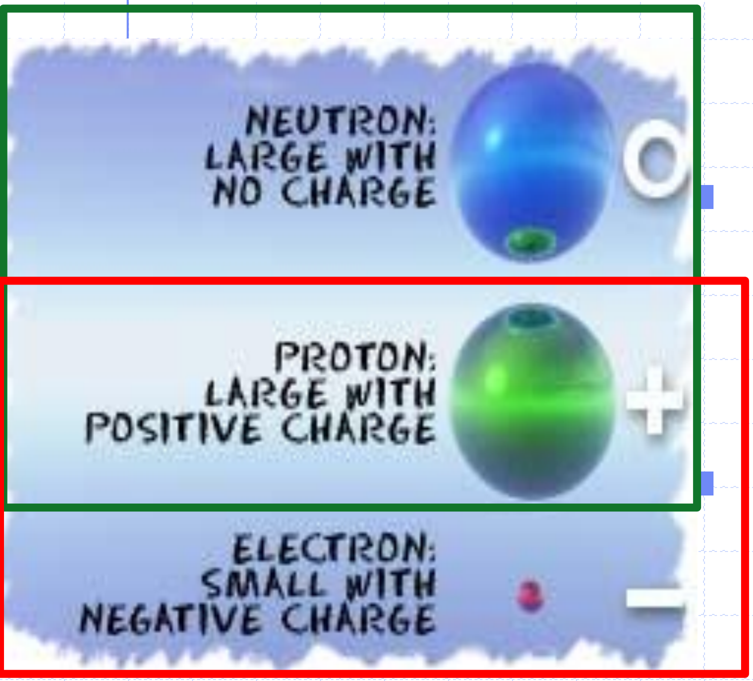
2.1.3 – Z, A, and isotopes

- 2.1.3 – Define the terms mass number (A), atomic number (Z) and isotopes of an element
  - The **atomic number** (Z) is the number of protons in the nucleus
  - The total number of protons and neutrons in an individual atom is known as the **mass number** (A). Electrons are negligible in the calculation
  - **Nuclides** of a chemical element are described by the following notation:

Mass# → 12; Charge → 4+; Atomic # → 6

$$^{12}_{6}C^{4+}$$

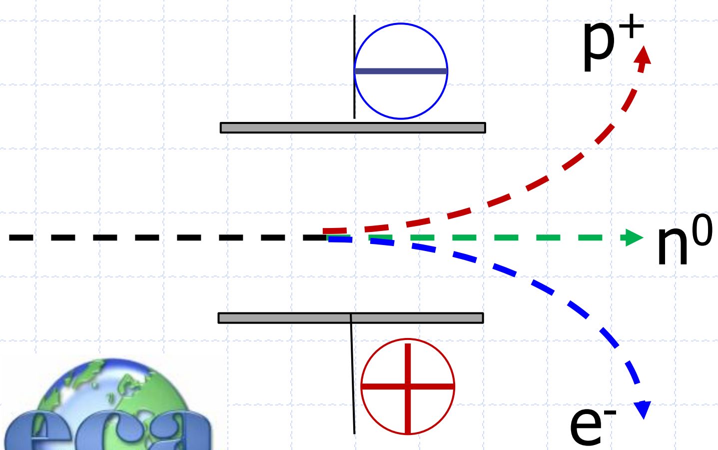
2.1 – Differing sub-atomic particles

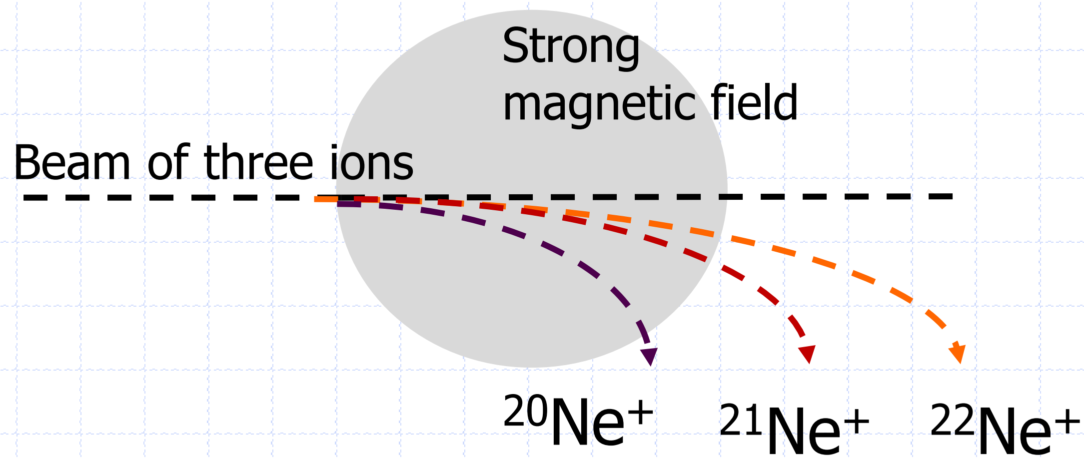


- An **ion** is a charged particle with a differing number of protons and electrons
- A **cation** is an ion with a positive charge (the element has lost electrons – P>N)
- An **anion** is a ion with a negative charge (the element has gained electrons – P<N)
- Individual atoms of the same element that have different mass numbers are called **isotopes**

2.1 – Deflection of sub-atomic particles

- Moving charged particles such as protons, electrons (cathode rays) and ions are deflected by electric and magnetic fields in an evacuated vacuum tube
- Charged sub-atomic particles (and ions) that enter a magnetic field are deflected from their straight line path to follow the arc of a curve dependent on their charge to mass ratio (m/z)





2.1.4 – Simple Symbols and Calcs

- 2.1.4 – Deduce the symbol for an isotope given its mass number and atomic number
  - Mass Number (A) = p + n
  - Atomic Number (Z) = p
  - Therefore, A – Z = n
- Likewise, the charge and atomic number can be related to find the number of electrons
  - Atomic number (Z) = p
  - Charge (z) = relative electrons to protons
  - Therefore, Z – z = charge of species

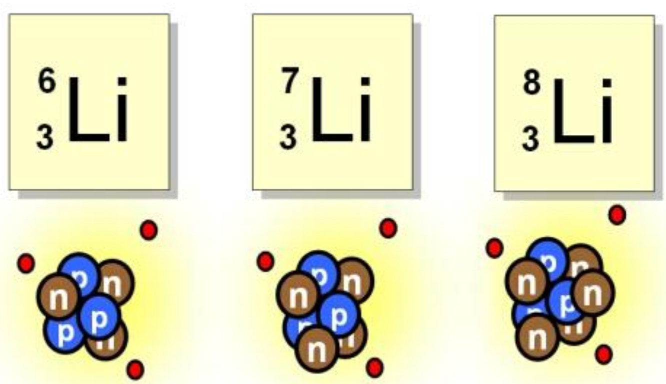
2.1.5 – Sub-atomic Composition

- 2.1.5 – Calculate the number of protons, neutrons and electrons in atoms and ions from the mass number, atomic number and charge

Name	Symbol	Protons	Neutrons	Electrons
Beryllium	$^{9}_{4}Be$	4	5	4
Oxygen	$^{17}_{8}O$	8	9	8
Neon	$^{21}_{10}Ne$	10	11	10
Fluorine	$^{19}_{9}F$	9	10	9
Oxygen	$^{18}_{8}O$	8	10	8
Magnesium ion	$^{24}_{12}Mg^{2+}$	12	12	10
Chloride ion	$^{37}_{17}Cl^{-}$	17	20	18
Aluminum ion	$^{27}_{13}Al^{3+}$	13	14	10
Calcium ion	$^{40}_{20}Ca^{2+}$	20	20	18

2.1.6 – Isotopic Properties

- 2.1.6 – Compare the properties of the isotopes of an element
- Isotopes of the same element have identical chemical properties (since electrons are the same) but have slightly different physical properties
- Lighter isotopes diffuse more rapidly due to a slight decrease in van der waals forces



2.1.6 – Isotopes in CO_2

- Carbon dioxide consists of one carbon and two oxygen atoms in a fixed ratio.
- There are two stable isotopes of each
  - Carbon-12 (^{12}C) and Carbon-13 (^{13}C)
  - Oxygen-16 (^{16}O) and Oxygen-17 (^{17}O)
  - Therefore six stable forms of CO_2 exist, ALL with the same chemical properties (due to electrons)
  - $^{12}C^{16}O_2$, $^{12}C^{16}O^{17}O$, $^{12}C^{17}O_2$
  - $^{13}C^{16}O_2$, $^{13}C^{16}O^{17}O$, $^{13}C^{17}O_2$

2.1.7 - Radioisotopes

- 2.1.7 – Discuss the use of radioisotopes
- A number of chemical elements contain unstable nuclides which break up spontaneously with the emission of ionizing radiation
  - The unstable particles are known as **radioactive** and are called **radioisotopes.**
  - There are three types of radiation, Alpha, Beta, and Gamma

2.1.7 – Radiation of particles

Radiation	Relative Charge	Relative Mass	Nature	Penetration	Deflection by electric field
Alpha particles	+2	4	2 protons 2 neutrons	Stopped by a few sheets of paper	Low
Beta particles	-1	1/1837	Electron	Stopped by a few mm of plastic of aluminum	High
Gamma rays	0	0	Electromagnetic radiation of very high frequency	Stopped by a few cm of lead	None

2.1.7 – Radioactive Decay

- During beta and alpha decay a more stable isotope is formed
- Beta-decay: (neutron splits into a 1p + 1e)
  - Carbon-14 (used for carbon dating)
    - $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$
- Alpha-decay (particle with 2p + 2n emitted)
  - $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$
- Gamma Radiation generally accompanies alpha and beta decay and is the emission of high energy electromagnetic rays